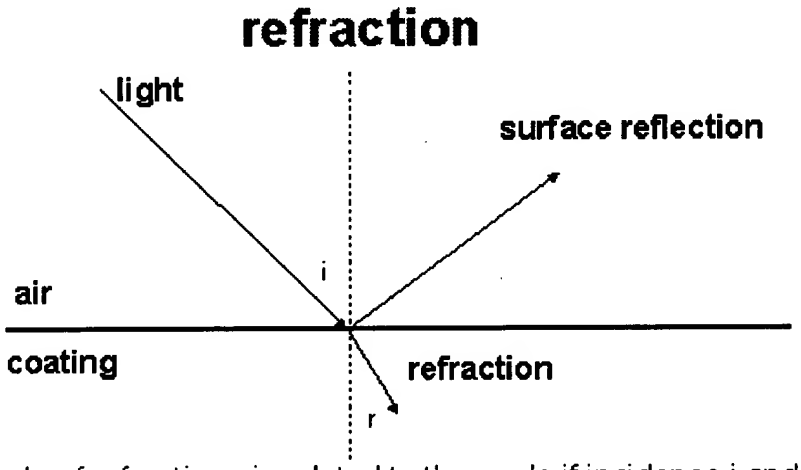
What happens when light strikes the surface of a material?

When light strikes a surface there are two things that can happen: (i) the change in refractive index can cause light to be reflected by the surface and this surface-reflected light is called specular reflection; (ii) light that is not reflected at the surface can penetrate the body of the material although as it passes through the surface the change in refractive index slows down the speed of light and this causes the light to be refracted.



The angle of refraction r is related to the angle if incidence i and the refractive index of the coating n_2 and air n_1 thus

$$\sin i / \sin r = n_1 / n_2$$

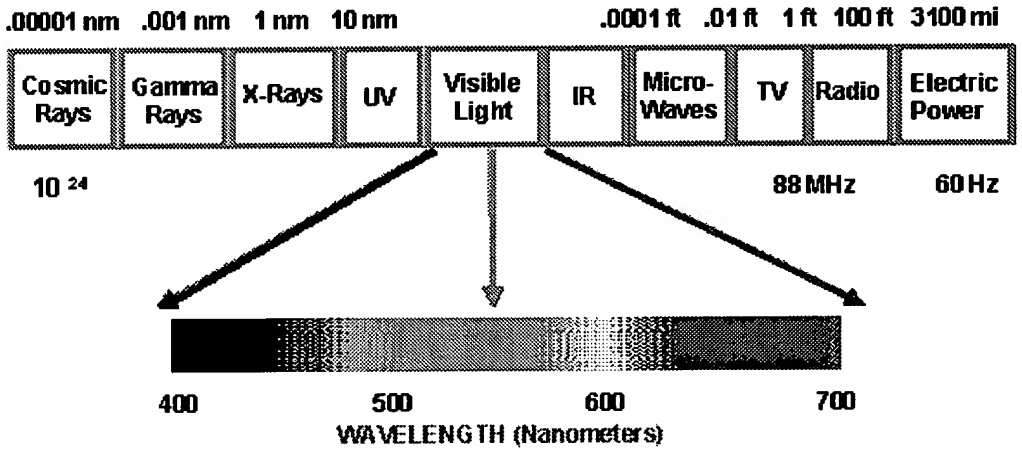
E.g. if $n_2 = 1.5$ and $n_1 = 1.0$ and $i = 45^0$ then $r = 28^0$

Light may pass completely through a material, in which case we say that it has been transmitted. Alternatively the light may be absorbed by the material or it may be scattered. Light that is scattered or reflected may eventually pass out of the front, back, or side of the material.

What is the colour spectrum?

The modern understanding of colour originated in the discovery of the spectral nature of light by Isaac Newton in the 1600s. Newton considered light to be a stream of particles. His experiments with prisms showed that white light can be split into individual colours. Furthermore, he noted that light of different colours had different refrangibility. Blue light is refracted more than red light, for example, when it passes from air into a medium of higher refractive index such as a prism. We now know that Newton's famous experiments demonstrated that light consists of energy of different wavelengths.

electromagnetic spectrum



The eye is sensitive to a broad band of wavelengths with the approximate range 350-750 nm. The visible spectrum represents only a small fraction of the full electromagnetic spectrum. Within the visible spectrum certain wavelengths give rise to certain visual sensations. For example, the shorter wavelengths are perceived to be violet and blue. It is important, however, to understand that the use of terms such as *blue light* is for convenience only and that this use is not intended to contradict the fact that colour exists only in the mind.

How is light absorbed?

Light can be absorbed by materials according to a number of mechanisms that include atomic vibrations and rotations, ligand-field effects, molecular orbitals, and charge transfer. It is very often the case that specific quantities of light (energy) are absorbed by a specific material and thus the light absorbtion properties of materials are usually wavelength selective.

The energy that is absorbed by molecules can be dissipated as kinetic and heat energy, but sometimes the energy can be re-emitted. Fluourescence and phosphorescence are phenomena that result from the re-emission of absorbed light energy: in both cases the re-emitted energy is at a longer wavelength than the light originally absorbed.

How is light scattered?

When light strikes particles it may be scattered. When the scattering particles are extremely small (to the order of 1000 nm) the light is scattered according to a simple law proposed by Rayleigh: short wavelengths are scattered more than long wavelengths. For larger particles (to the order of 4000 nm and larger) the amount of scattering is according to Fresnel's equations: the amount of scattering depends upon the difference between the refractive index of the particle and of the medium in which it is dispersed and this difference is wavelength dependent.

If light is scattered evenly in all directions this is called isotropic scattering but it is rarely the case. The absorption and scattering properties of partices are complex and a number of theories exist to describe them including the Kubelka-Munk theory.

Why are some substances coloured?

There are many reasons why substances appear coloured but for most physical materials it is because the absorption and scattering properties of the material are different for different wavelengths of light. Thus a substance that appears yellow may do so because it absorbs most strongly in the blue part of the spectrum and scatters most strongly in the red and green parts of the spectrum. It is often the case that a pigment scatters light most efficiently in one region of the spectrum whilst having its main absorption band in another. This explains why translucent and transparent coloured films can have different hues when viewed by reflected as opposed to transmitted light.

Frequently asked questions about Colour Physics

version 2.0a

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About this FAQ

This FAQ concerns the measurement and control of coloured surfaces such as plastics, textiles, surface coatings etc. It is intended for practitioners rather than theoreticians. Those requiring a more theoretical introduction to colour science or information about digital colour image reproduction should, in my opinion, start by consulting the Poynton Colour FAQ. If your question is not in the FAQ you may wish to consider version 3.0 of the FAQ. This enhanced version contains understandable but accurate answers to 60 of the most common question on the topic of colour physics. The document contains 20 pages (approx. 9000 words) and 21 diagrams and can be obtained for a small fee from the **Colourware Color Shop**. Alternatively you may wish to post your question on the **Colourware Color Forum** where it may be answered by Colourware staff or other members of the forum. For more serious study, why not visit our **bookstore** for our special collection of books on colour science.

Light and Matter

Colour Vision

CIE Colour Specification

Colour Difference Evaluation

Miscellaneous Topics

Note:

This FAQ has been prepared by Dr Stephen Westland at Colourware. If you have any comment regarding this document I can be contacted at steve@colourware.co.uk or visit my page at Derby University. This FAQ is provided free of charge - please help to maintain this useful resource by visiting our sponsors, Minolta (UK) Ltd.